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COMPLETE SPECIFICATION

Improvements in or relating to Laminated Material and Method and Apparatus for the Manufacture thereof

I, MARC ALFRED CHAVANNES, a Swiss citizen, of 57 Montague Street, Brooklyn 1, New York, State of New York, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a laminated structure having closed cells defined therein and suitable for use, for example, as a cushioning material or for shock-absorbing purposes in packaging of products; for the padding of furniture or trimming or lining cars or trucks; or for heat insulation and like purposes.

An object of the invention is to provide a novel effective method of sealing together to form a laminated structure, two films of thermoplastics or material having a thermoplastic stage (hereinafter referred to as thermoplastics) in such a manner as to define, between such films, a plurality of cells wherein air is entrapped, which permits of rapid and continuous production of the structure whilst ensuring efficient sealing together of the films.

With this object in view, the present invention provides a method of producing a laminated structure having hollow, closed cells defined therein and suitable for use, for example, as a cushioning material comprising: heat-treating a first film of thermoplastics until at least one surface thereof is at its fusing temperature, heat-treating a second film of thermoplastics until at least one surface thereof is at its fusing temperature, thereafter passing the first film over an embossing roller provided with a plurality of surface cavities with a film surface which is at its fusing temperature remote from the embossing roller, depressing the first film into the surface cavities, and thereafter applying the second film to the first film under pressure, a surface of the second film which is at its fusing temperature being arranged to contact the non-depressed parts of the surface of the first film which is remote from the embossing roller whereby the second film becomes welded to the first film without rupturing either film, the combined films forming the said laminated structure which is thereafter stripped from the embossing roller by a separate non-embossing stripping roller.

The invention further provides apparatus for producing a laminated structure, having hollow closed cells defined therein, and suitable for use, for example, as a cushioning material, comprising means for heat-treating a first film of thermoplastics until at least one surface thereof is at its fusing temperature and for leading the first film in its heated condition over an embossing roller provided with a plurality of surface cavities and arranged so that a surface of the film which is at its fusing temperature is remote from the embossing roller, means for depressing the heat-treated first film into the surface cavities, means for heat-treating a second film of thermoplastics until at least one surface thereof is at its fusing temperature, means for feeding the second film in the heated condition onto the first film on said embossing roller at a point beyond that at which the first film is depressed into the surface cavities with a surface of the second film which is at its fusing temperature contacting the non-depressed portions of the first film, means for applying pressure to the films to cause them to become welded together, without rupturing of either film, to form said laminated structure, and a separate non-embossing stripping roller co-operating with the embossing roller for removing the laminated structure therefrom.

The fusing temperatures for certain thermoplastics are set out in a table hereinafter.

The invention further includes, of course, laminated structures produced by the method defined above.

In order that the invention may be fully understood, it will be described further, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a diagrammatic side elevation illustrating a first embodiment of apparatus suitable for carrying the method of the invention into effect;

Fig. 2 is a view similar to that of Fig. 1 but showing a second embodiment of the apparatus;

Figs. 3, 4 and 5 are similar views showing respectively third, fourth and fifth embodiments of the apparatus;

Fig. 6 is a part-sectional exploded perspective view of a first embodiment laminated structure produced by the method of the invention;

Fig. 7 is a plan view corresponding to Fig. 6;

Fig. 8 is a diagrammatic fragmentary cross-sectional view showing a moulding roller which may form part of the various embodiments of apparatus shown in Figs. 1 to 5, the section corresponding to the line 8—8 of Fig. 9;

Fig. 9 is a fragmentary front elevation of the moulding roller of Fig. 8;

Fig. 10 is an enlarged fragmentary cross-section taken on the line 10—10 of Fig. 7;

Fig. 11 is a view, similar to Fig. 6, showing a second embodiment of laminated structure produced by the method of the invention;

Fig. 12 is a plan view corresponding to Fig. 11;

Fig. 13 is a view similar to Fig. 10, but showing a third embodiment of the laminated structure;

Figs. 14, 15 and 16 are views similar to Figs. 10 and 13 but showing fourth, fifth and sixth embodiments respectively of the structure;

Fig. 17 is a fragmentary part-sectional exploded view showing a cushioning assembly composed of two laminated structures according to the invention;

Fig. 18 is a fragmentary plan view showing the assembly of Fig. 17;

Fig. 19 is an enlarged cross-sectional view taken on the line 19—19 of Fig. 18;

Fig. 20 is a view similar to Fig. 19, but showing a modification thereof; and Fig. 21, 22 and 23 are views similar to Fig. 10, but showing respectively seventh, eighth and ninth embodiments of laminated structure produced by the method of the invention.

Referring firstly to Fig. 1 of the drawings, this figure illustrates a simple manner of carrying the invention into effect. The apparatus illustrated comprises a rotating moulding roller 10 which is provided, in its outer curved surface, with a plurality of cavities and which preferably embodies vacuum moulding means. The cavities may be of any desired configuration. For instance they may be hexagonal as shown in Figs. 8 and 9 and as will later be described.

A first film 11 of a mouldable thermoplastics is fed to the moulding roller 10 by means of guide rollers 12, 13 and 14. These guide rollers 12, 13 and 14 are preferably heated rollers which are heated to successively higher temperatures so that the temperature of the film 11 is raised progressively as it passes successively around said rollers, the film 11 passing onto the embossing roller 10 at a predetermined temperature approximating to that at which the thermoplastics of the film 11 is fusible. The temperatures of the heated rollers will, therefore, depend upon the material of the film 11. For instance, in the case of a low-density polyethylene film 11, the roller 12 will be maintained at approximately 180° F to 200° F while the rollers 13 and 14 will be maintained at about 230° F to 240° F.

Once in contact with the embossing roller 10, the first film 11 is maintained at its fusing temperature by a heater 15 and the vacuum moulding means (not shown) operates to draw into the cavities those portions of the first film 11 which overlie such cavities, so that depressions corresponding to the shapes of the cavities are formed in the first film 11. The use of the heater 15 may, if desired, be obviated, where the embossing roller 10 is of a heat-conducting material, by providing a surface covering, on the outer curved surface of such roller 10, (i.e. on the portions 10^1 between the cavities—see also Figs. 8 and 9) a covering of heat-insulating material. In this case, the portions of the film 11 which are drawn into the cavities to form the depressions become cooled by contact with the walls defining the cavities, whereas the non-depressed portions of the film (which portions contact the heat-insulating covering) retain their heat and cool less rapidly for a purpose which will shortly become apparent.

The film 11, with its non-depressed portions maintained at about the temperature at which the thermoplastics is fusible either by the heater 15 or by reason of being insulated from contact with the heat-conducting material of the embossing roller 10, is carried by the embossing roller 10 towards a pressure roller 19 which serves to guide a second film 16 onto the first film 11, whilst on the roller 10, so as to overlie the depressions therein. In moving onto the first film 11, the second film 16 passes over guide rollers 17 and 18 as well as the pressure roller 19, and these rollers (like the guide rollers 12, 13 and 14) are formed as heating rollers which serve

to heat the second film 16 progressively so that it passes onto the first film 11 at its fusing temperature.

As the two films 11 and 16 are brought together, fusion of the second film 16 to the non-depressed portions of the first film 11 occurs, the pressure roller 19 serving to apply pressure to the two films with the cooperation of the embossing roller 10. As the embossing roller 10 continues to rotate, it carries the laminated structure formed by the fusing together of the two films around to a stripping roller 20 during which the structure (indicated by reference numeral 21) cools, the stripping roller 20 then serving to strip the structure 21 from the embossing roller 10 and to feed it e.g. for further processing or for packaging in rolls or other suitable forms.

The pressure applied by the pressure roller 19 is a factor affecting the fusion together of the films. Assuming the films both to be of low density polyethylene of a few thousands of an inch in thickness and the rollers 12, 13, 14, 17, 18 and 19 to be heated to the temperatures previously mentioned a pressure of from 30 to 60 pounds per square inch at the pressure roller 19 is satisfactory. The pressure required to obtain efficient fusion of the films is, however, essentially an inverse function of the film temperature.

Referring now to Figs. 8 and 9, these figures show one form of embossing roller 10 suitable for use in the apparatus of Fig. 1 (and also the embodiments of apparatus of Figs. 2 to 5, yet to be described) and which will be instrumental in producing a laminated structure such as is shown in detail in Fig. 6, 7 and 10.

As can be seen in Figs. 8 and 9, the cavities therein are hexagonal in shape and the bottom of each cavity connects with vacuum moulding means including a respective passage 22, for each cavity, said cavities communicating with a manifold 23. Thus, as the first film 11 passes onto the embossing roller, vacuum applied to the cavities by way of the manifold 23 and the passages 22 serves to draw into such cavities those portions of the film 11 which overlie the cavities, thereby forming, in the film 11, hexagonal depressions or embossments 24 (see Figs. 6, 7 and 10). Fig. 6 shows the second film 16 separated from the first film 11 purely for the purposes of illustration, but it will be seen from Fig. 10 that the second film 16 is fused to the first film 11 where contacted by the non-embossed portions of the latter, so that the depressions 24 together with the second film 16 define between them a plurality of closed cells in the finished laminated structure. Tests have shown that the method of the invention provides for airtight sealing of each of the cells.

Fig. 10 also shows that, due to the drawing effect which occurs when the corresponding portions of the first film 11 are drawn into the cavities in the embossing roller 10, the sidewalls 80 of the depressions or embossments 24 taper from a maximum thickness where they connect with the non-depressed portions of the film 11 to a minimum at the extremities of the depressions 24 remote from the non-depressed portions of the film 11.

Referring now to Figs. 2 to 5 these figures show alternative practical embodiments of apparatus for producing the laminated structure, and similar reference numerals have been allocated to parts thereof which are similar to parts already described with reference to Fig. 1.

In the apparatus of Fig. 2, the embossing roller 10 is fed with a first film 25 by guide rollers 26, 27, 28 and 29 of which at least the rollers 27, 28 and 29 are formed as heated rollers which serve, as in the arrangement of Fig. 1, progressively to heat the first film 25 so as to feed it to the embossing roller 10 at a general temperature whereat it is mouldable and can be fused readily to a second film 31. Depressions are formed in the first film 25 in exactly the same way as in the preceding example but the second film 31 is fed directly from extrusion apparatus 32 by way of a pressure roller 30 onto the first film 25. Since the second film 31 will normally leave the extrusion apparatus 32 at a temperature higher than that necessary to ensure efficient fusion of such film 31 with the first film 25, the pressure roller 30 is preferably cooled so as to cool the second film 31.

Fusion together of the films 25, 31 to produce the laminated structure 37 occurs as in the preceding example, and after cooling whilst travelling on the embossing roller 10, between the pressure roller 30 and a stripping roller 33, the finished structure is conducted away from the embossing roller 10 by the stripping roller 33 and successive rollers 34, 35 and 36, of which the rollers 34 and 35 may be cooled to ensure complete cooling of the structure 37.

Fig. 3 shows an arrangement wherein both films are continuously extruded. In this case, the first film 47 is extruded by an extruding apparatus 48 onto a guide roller 49 from which it passes onto the embossing roller 10.

An endless belt 50 serves to maintain the first film in contact with the guide roller 49 as it passes around the latter, and this belt passes around belt rollers 51, 52 and 53 which together with the guide roller 49, may be cooled to ensure that the film 47 passes onto the embossing roller 10 at a temperature suitable for depressions to be formed therein in a manner similar to that already described, and for subsequent fusion of a second film 41 thereto.

The second film 41 is similarly extruded, by means of an extruder 40 onto a guide roller 42 against which such film 41 is held

by an endless belt 43 running around the belt rollers 44, 45 and 46 some or all of which are cooled to cool the extruded film 41 to a suitable temperature for being fused to the first film 47. As with the preceding examples, the guide roller 42 acts as a pressure roller and applies the second film 41 onto the first film 47 after depressions have been formed in the latter, whilst at the same time causing fusion of such second film 41 to the non-depressed portions of the first film 47.

The resultant laminated structure 55 cools as it passes around the embossing roller 10 and is stripped therefrom by a stripping roller 54 which may, if desired, feed the laminate to further cooling rollers (not shown).

The arrangement of Fig. 4 is somewhat similar to that of fig. 3 in that both the films are extruded and passed directly to the embossing roller 10. In this case, however, a double extruder 60 produces both the first film 61 and the second film 62.

The first film 61 is fed to the guide roller 63 which transfers it to the embossing roller 10 for production of the depressions therein, an endless belt 64, similar to the belt 50 of Fig. 3, carried by belt rollers 65, 66 and 67 and serving to hold such first film 61 against the guide roller 63.

The second film 62 is extruded onto a pressure roller 62^1 which applies the such second film 62 to the first film 61, after embossment of the latter by the embossing roller 10, and is fused thereto as in the preceding examples. The resultant laminated structure 68 cools as it is carried around by the embossing roller 10 from the pressure roller 62^1 to a stripping roller 69 which removes the structure 68 whereafter it may be further cooled or processed as may be desired.

In certain instances, it may be desirable to provide a laminated structure composed of two films which are welded together and each of which has depressions therein, and Fig. 5 shows a form of apparatus suitable for preparing such a structure. In this embodiment of the apparatus, a first film 70 is fed by a heated guide roller 71 to a rotating embossing roller 72 which is substantially similar to the embossing roller 10 of the preceding embodiments. As the embossing roller 72 rotates it creates the depressions in the first film 70 and then moves it past a heater 78 which maintains such film substantially at a temperature which is suitable for fusion of the first film 70 to a second film 73. The latter is fed by a guide roller 74 onto a vacuum moulding belt 75 guided, by belt rollers 76, 77 and tensioned by a tensioning roller 79 so that one run of such belt 75 passes partially around the moulding roller 72. Cavities are provided in the belt 75 in the same way as they are provided in the embossing roller 72, and such cavities are similarly spaced to those in the roller 72, the belt 75 and roller 72 being coordinated so that the cavities register with one another.

The belt 75 moves the second film 73 past the heater 78 which maintains such film 73 at a temperature suitable for the fusion thereof to the first film 70. Such fusion is effected in this case by the belt 75 pressing the second film 73 against the first film 70 under the tension applied by the tensioning roller 79.

It will be appreciated of course, that in this embodiment of the apparatus, either or both of the films 70 and 73 may be fed directly from a respective extruder, and a moulding roller similar to the rollers 10 and 72 could be used in place of the embossing belt 75, such roller serving both to produce depressions in the second film 73 and as a pressure roller to apply the second film 73 to and fuse it to the first film 70 on the embossing roller 72.

The form of the laminated structure produced by this apparatus is illustrated generally in Fig. 23 and will be described later in detail.

If the described methods are carried into effect at normal atmospheric pressure, cooling of the resultant laminated structure will result in contraction of the air sealed into each of the cells defined by the depressions in the first film and the second film extending thereacross, so that each of such cells will, naturally, become slightly deflated upon cooling of the structure. In certain applications, it may be desirable that the air in such cells should, after deflation of the structure be at a pressure substantially equal to or slightly greater than atmospheric, and this can be achieved, for example, by carrying out the method at a pressure higher than atmospheric pressure. Alternatively, it is possible, after cooling of the laminated structure, to reheat the structure so that it becomes slightly plastic and shrinks to a small degree so that the resultant contraction of the cells produces somewhat smaller, but fully inflated cells.

As previously stated, the temperatures at which the films are fused together will depend upon the material of such films, so that the temperatures at which the films are applied to the embossing rollers or belt will be varied accordingly. The following table indicates the fusion temperatures of various typical thermoplastics which may be employed for the films used in forming the laminated structure according to the invention:

FUSION TEMPERATURE TABLE

Class of material to be fused.	Fusion Temperatures in Degrees Fahrenheit
Polyvinyl chloride and its copolymers - -	325° to 350°
Polyethylenes (low and medium density) -	240° to 270°
Polyethylene (high density) - - - -	270° to 320°
Polystyrenes - - - - - - -	250° to 275°
Polypropylenes - - - - - -	280° to 330°

Various embodiments of the laminated structure produced in accordance with the invention are shown generally in Figs. 6, 7 and 10 to 23. The form of the invention shown in Figs. 6 and 7 has already been described and involves the utilization of hexagonal sealed depressions 24, and in Fig. 10 it will be observed that each depression 24 has side walls 80 which taper so that the thinnest portion of the wall is furthest from the sealing film 16. The achievement of this has also previously been described. The utilization of the tapered wall structure as indicated at 80 provides, in the laminated structure, mechanical shock-absorbing action which supplements the pneumatic action arising from the air sealed in the cells of the structure. The cells normally contain air sealed therein and when pressure is applied to compress such cells, the walls, thereof will tend to expand and permit each cell to be compressed. In many cases there is a point beyond which further compression cannot be withstood without rupturing the depressions 24. In such an instance, the wall 80 will provide further support and, as the depression 24 itself is crushed, the walls 80 will afford increasing resistance until such time as the structure is completely destroyed. Thus, the structure of Figs. 7 and 10 provides mechanical, as well as pneumatic, shock-absorbing action and such latter action is ideal when the material is employed to protect objects which may be dropped from high elevations and which require substantial shock-absorbing action even though the shock absorbers are crushed during impact with the ground. One such instance would be in the dropping of articles from aircraft, wherein it is merely necessary to provide means to protect the articles against being damaged upon impact with the ground.

The depressions 24 may be made of any desired shape or configuration with uniform or tapered walls and a modified structure is shown in Figs. 11 and 12. In this case, the sealed depressions, denoted by the numeral 82, are circular in configuration and will afford a somewhat modified cushioning action.

Another consideration in the fabrication of the structure in accordance with the invention is the thickness of the films to be laminated. As the films are increased in thickness, additional shock-resisting action will be provided. In certain cases, it may be desirable to use a first film of a fairly small gauge for instance from 1 to 5 thousandths of an inch in thickness, while the second film may be relatively stiff to lend support to the structure. Thus, any number of variations may be made in the thickness of the sealed films and the size and configurations of the depressions to attain any desired shock-absorbing characteristics.

Fig. 13 illustrates still another embodiment of the structure wherein the sealed depressions denoted herein by the numeral 83, are hemispherical in form. A hemisphere has been found to provide a shock-absorbing action different from that of the invention shown in Figs. 6 and 11, since the hemispheres can be compressed with a lighter force than that required to initiate compression on the previously described forms of the depressions, although the maximum resistance obtained from the hemispherical configuration is substantially the same as that obtained in the previous forms. With the hemisphere, however, the use of the tapered wall 84, while lending mechanical shock-absorbing action, will not provide the degree of shock-absorbing action that would be obtained, for instance, by the form of the invention shown in Figs. 6 and 10.

In certain cases, it may be desirable to combine the laminated structure produced in accordance with the invention with other laminar materials. In the case of packaging, for instance, it may be desirable to apply a coated paper to one side of the structure, and this is illustrated in Fig. 14 wherein the paper, denoted by the numeral 85, is laminated to the second film 86 of a laminated structure comprising an embossed first film 87 to which the second film 86 has been fused in the manner described in connection with any of Figs. 1 to 4.

When the laminated structure is to be utilized for furniture, rug padding or other similar applications, it may be desirable to utilize a fabric backing 88 as illustrated in Fig. 15. In the case of paper and fabric laminates, as shown in Figs. 14 and 15, the paper 85 or fabric 88, as the case may be, is preferably first coated with or laminated onto the second film 86 prior to sealing the latter to the first film 87, though other procedures may be used to attain the structure.

Fig. 16 illustrates still another embodiment of the structure produced by the method of the invention wherein an embossed first film

89 is provided with a sealing or second film 90 fused thereto to provide a plurality of sealed cells 91 and a further film 92 is sealed to the extremities of the depressions in the first film 89 remote from the non-depressed parts of such film to provide a laminated material having two essentially plane surfaces. The further film 92 in this embodiment is substantially parallel to the second film 90, and it may be attached to the first film 89 by heat sealing or by means of an appropriate adhesive, it being merely necessary to effect a good mechanical bond between the films 89 and 92, as a hermetic seal is unnecessary. This structure provides for uniform pressure distribution between the sealed cells 91 and, if desired the peripheral edges of the structure may be sealed by sealing the second and further films 90 and 92 together, in order to prevent the entrance of foreign matter, insects and the like. This is particularly important when the structure is to be utilized as a furniture packaging material or for other similar purposes.

Figs. 17 to 19 illustrate an arrangement wherein two laminated structures produced in accordance with the invention are combined to provide a single composite assembly. It will be observed from Fig. 17 that two separate laminated structures, denoted respectively by the numerals 93 and 94, are provided with the sealed depressions 93^1 and 94^1 thereof arranged in relatively widely spaced relationship. Each of the structures 93 and 94 corresponds essentially to the structures shown in Figs. 11 and 12 and may be of composed solely of two films sealed together or may have one of the films combined with other materials as described with reference to Figs. 14 and 15. The structures 93 and 94 are secured in overlying face-to-face relationship, with the sealed depressions 93^1 located between the depressions 94^1 and vice versa, so that the total thickness of the assembly is not appreciably greater than the total thickness of either one of the structures 93 and 94. The combined assembly is illustrated in Fig. 18 with the depressions 93^1 shown in full lines while the depressions 94^1 are shown in dotted lines. The relative dispositions of the depressions 93^1, 94^1 may be observed more clearly in Fig. 19 which shows that the resulting cells are substantially in a continuous relationship and thereby afford great structural strength.

Fig. 20 illustrates still another form of the structure produced by the method of the invention wherein the laminated films are enclosed between barrier layers which protect the structure against gas and moisture vapour. In this form the structure includes a suitably moulded first film 95, a second film 96, an overlying third film 97, and upper and lower barrier layers 98 and 99 respectively of aluminium foil or other similar material. The edges 100 of the films 96 and 97 and the barrier layers 98 and 99 are sealed about the entire periphery of the structure so as to be completely protected.

In certain applications it is desirable to combine the resilient qualities of materials such as foamed rubber with the cushioning qualities of the laminated structure of the invention. For this purpose, a modified structure, as shown for example in Fig. 21, may be employed wherein the laminated structure (such as shown in Fig. 7 for instance) denoted generally by the reference numeral 21 may be combined with a layer of foamed rubber 101 cemented or otherwise adhered to one side thereof. While rubber and rubber-like materials can be fabricated with a variety of resilience, they cannot afford the advantages of the structures produced in accordance with the invention. However, should a wide range of cushioning action be desirable, it has been found advantageous to combine a layer of foamed rubber or foamed synthetic rubber having a very soft cushioning characteristic, with a laminated structure embodying a plurality of sealed elements in accordance with the invention. Thus the characteristics of the two materials will afford a composite structure that will provide a shock-absorbing and cushioning action not heretofore attainable with known structures. It is also apparent that dense resilient materials may be utilized, depending on the character and nature of the shock-absorbing and cushioning actions desired.

Fig. 22 illustrates a further embodiment of the invention wherein the laminated structure, such as the structure 21 previously described, is completely enclosed within natural or synthetic rubber materials of any desired density. One layer 102 of the natural or synthetic rubber is adhered to one side of the second film while a second layer 103 is adhered to the other side of the structure with the material of the layer 103 filling spaces between the sealed depressions 24. In this way the material of the layer 103 not only affords additional resiliency, but lends support for the depressions 24. This form of the invention is particularly useful for furniture padding, mattresses and the like and is inexpensive even though it provides a particularly good cushioning action.

Fig. 23 illustrates still another modification of the structure involving the sealing of two embossed films in back-to-back relationship. In this form of the structure two embossed films 104 and 105 each having a plurality of depressions 104^1 and 105^1 respectively are heat sealed one to the other to form a plurality of sealed cells.

The improved fusing technique in accordance with the invention wherein a moulded film is heat-sealed to a second film by properly maintaining at least the mating surfaces

at a temperature suitable for fusing before pressing them together to form a substantially unitary resultant structure permits the introduction of other materials between the sealed layers for moisture-vapour-proofness, protection against fungi, bacteria, insects or rodents, fireproofing and similar purposes. For instance, just prior to the heat-sealing of the second film to the embossed first film, powdered calcium silicate or calcium stearate can be introduced to absorb moisture and water vapour and provide a completely dry atmosphere within the sealed cells. If desired, a suitable compound of boron and ammonium sulphate may be introduced between the films immediately prior to the fusion, for fireproofing purposes.

It will evident from the foregoing description that the films employed in carrying out the present invention may be of polyvinyl chloride and its co-polymers, polyethylenes, polystyrenes and polypropylenes, all of which are so-called "thermoplastics". It will also be apparent from the description, particularly relative to Figs. 1 to 5, that in carrying the invention into effect the first film at least must be capable at an elevated temperature of being moulded to enable the depressions to be formed therein and that both the first and second film must be capable of being fused together at an elevated temperature, with the application of pressure thereto. In addition to the thermoplastics already enumerated, polyolefins, co-polymers of vinyl chloride with vinyl acetate, polyvinylidene chloride and polyvinyl butyral can also be employed. Furthermore, use can be made of thermosetting plastics materials which have a thermoplastic stage, as well as materials which are mouldable before curing or vulcanising, such as natural and synthetic rubbers, for example butyl rubber.

The selection of the material of the films is, of course, material to the finished laminated structure, since soft cushioning will be provided if the structure is made using highly plasticised thin films, whilst firmer action is obtained with the use of heavy films incorporating only small amounts of plasticiser.

WHAT I CLAIM IS:—

1. A method of producing a laminated structure having hollow closed cells defined therein and suitable for use, for example, as a cushioning material comprising: heat-treating a first film of thermoplastics until at least one surface thereof is at its fusing temperature, heat-treating a second film of thermoplastics until at least one surface thereof is at its fusing temperature, thereafter passing the first film over an embossing roller provided with a plurality of surface cavities with a film surface which is at its fusing temperature remote from the embossing roller, depressing the first film into the surface cavities, and thereafter applying the second film to the first film under pressure, a surface of the second film which is at its fusing temperature being arranged to contact the non-depressed parts of the surface of the first film which is remote from the embossing roller whereby the second film becomes welded to the first film without rupturing either film, the combined films forming the said laminated structure, which is thereafter stripped from the embossing roller by a separate non-embossing stripping roller.

2. A method as claimed in the preceding claim wherein the first film is produced by a film extruder from which said first film passes onto the embossing roller.

3. A method as claimed in either preceding claim wherein the second film is produced by a film extruder from which said second film passes onto the first film on the embossing roller.

4. A method as claimed in claim 1 or claim 2 or claim 3 wherein the method is performed at a pressure exceeding normal atmospheric pressure, so that when the resultant laminated structure is subsequently transferred to normal atmosphere the pressure within the cells ensures that the latter are fully inflated.

5. A method as claimed in claim 1, 2, 3 or 4 wherein the resulting laminated structure is permitted to cool whilst still on the embossing roller.

6. A method as claimed in any preceding claim wherein the second film is formed with a plurality of depressions the spacings of which corresponds to the spacing of the depressions formed in the embossed first film, the second firm being applied to the first film with its depressions in register with those of the first film so that corresponding depressions in both films define each cell.

7. A method of producing a laminated structure suitable for use, for example, as a cushioning material, substantially as hereinbefore described with reference to the accompanying drawings.

8. Apparatus for producing a laminated structure, having hollow, closed cells defined therein and suitable for use, for example, as a cushioning material, comprising means for heat-treating a first film of thermoplastics until at least one surface thereof is at its fusing temperature and for leading the first film in its heated condition over an embossing roller provided with a plurality of surface cavities and arranged so that a surface of the film which is at its fusing temperature is remote from the embossing roller, means for depressing the heat-treated first film into the surface cavities, means for heat-treating a second film of thermoplastics until at least one surface thereof is at its fusing temperature, means for feeding the second film in the heated condition onto the first film on said

embossing roller at a point beyond that at which the first film is depressed into the surface cavities with a surface of the second film which is at its fusing temperature contacting the non-depressed portions of the first film, means for applying pressure to the films to cause them to become welded together without rupturing either film to form said laminated structure, and a separate non-embosing stripping roller co-operating with embossing roller for removing the laminated structure therefrom.

9. Apparatus as claimed in claim 8 including means for extruding the first film.

10. Apparatus as claimed in claim 8 or claim 9 including means for extruding the second film.

11. Apparatus as claimed in claim 9 or claim 10 wherein the or each extruder is arranged to feed its respective film over cooling rollers prior to its application to the embossing roller or the embossed film carried thereby.

12. Apparatus as claimed in any of claims 8 to 11, including external heating means for heating the first film whilst it is on the embossing roller prior to the application of the second film thereto.

13. Apparatus as claimed in any of claims 8 to 12, wherein the cavities in the embossing roller are connected to vacuum means whereby the depressions in the first film can be formed by a vacuum moulding.

14. Apparatus as claimed in any of claims 8 to 13, including embossing means for producing on the second film a plurality of depressions the spacing of which corresponds to the spacing of the depressions in the first film, the second film-feeding means being arranged to feed the second film with its depressions in register with those of the first film so that each cell is defined by a depression in the first film and a complementary depression in the second film.

15. Apparatus as claimed in any of claims 8 to 14 wherein the embossing roller is of a heat-conductive material the outer curved surface of which is provided with a covering of heat-insulating material.

16. Apparatus for producing a laminated structure suitable for use, for example, as a cushioning material, substantially as hereinbefore described with reference to and as illustrated in Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5 or Figs. 8 and 9 of the accompanying drawings.

17. A laminated structure suitable for use, for example, as a cushioning material when made by the method of any of claims 1 to 7.

18. A laminated structure as claimed in claim 17 wherein the depressions are hexagonal.

19. A laminated structure as claimed in claim 18 wherein the walls of the embossments taper in thickness from a minimum at the extremity of the embossment remote from the non-embossed portions of the respective film to a maximum where said embossments join with the non-embossed portions of said film.

20. A laminated structure as claimed in claim 17 wherein the depressions have cylindrical sidewalls.

21. A laminated structure as claimed in claim 17 wherein the depressions are substantially hemispherical.

22. A laminated structure as claimed in any of claims 17 to 21 further including a third film overlying the extremities of the depressions of the first film remote from the non-embossed portions of such film, and secured to said extremities so as to be substantially parallel to the second film.

23. A laminated structure as claimed in any of claims 17 to 22 further including a layer of material secured to that surface of the second film which is remote from the first film.

24. A laminated structure as claimed in claim 23 wherein the said layer of material is of paper.

25. A laminated structure as claimed in claim 23 wherein the said layer of material is of textile fabric.

26. A laminated structure as claimed in claim 23 wherein the said layer of material is of rubber.

27. A laminated structure as claimed in claim 23 wherein said layer is of a foamed thermoplastics.

28. A laminated structure as claimed in any of claims 17 to 27 wherein the films are enclosed between barrier layers for protecting the structure against gas or water vapour.

29. A laminated structure as claimed in any of claims 17 to 28 which is enclosed within a resilient material.

30. A laminated structure as claimed in claim 29 wherein the resilient material is natural or synthetic rubber.

31. A laminated structure as claimed in claim 29 or 30 wherein said resilient material is a foamed material.

32. A laminated structure as claimed in any of claims 17 to 31 wherein each cell contains a powdered material.

33. A laminated structure as claimed in claim 32 wherein the powdered material is fire-retardant.

34. A laminated structure as claimed in claim 32 wherein the powdered material is a desiccant.

35. An assembly comprising a pair of laminated structures as claimed in any of claims 17 to 21 secured together in face to face relationship with depressions of one of the structures located between corresponding depressions in the other structure.

36. A laminated structure as claimed in claim 17 and substantially as hereinbefore described with reference to and as illustrated in Figs. 6, 7 and 10; or Figs. 11 and 12; or Fig. 13; or Fig. 14; or Fig. 15; or Figs. 17 and 18; or Fig. 19 or Fig. 20; or Fig. 21; or Fig. 22; or Fig. 23 of the accompanying drawings.

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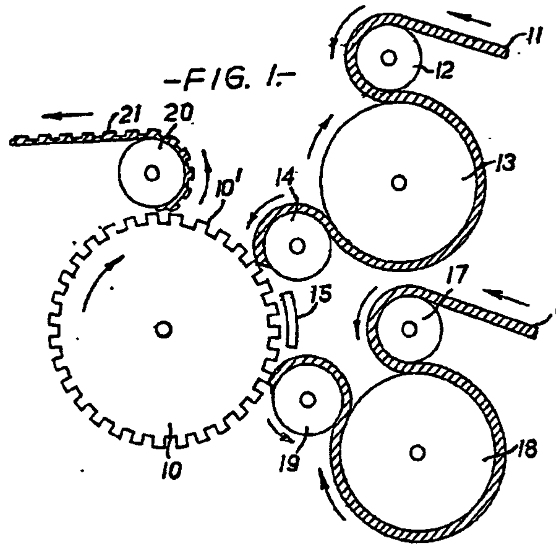
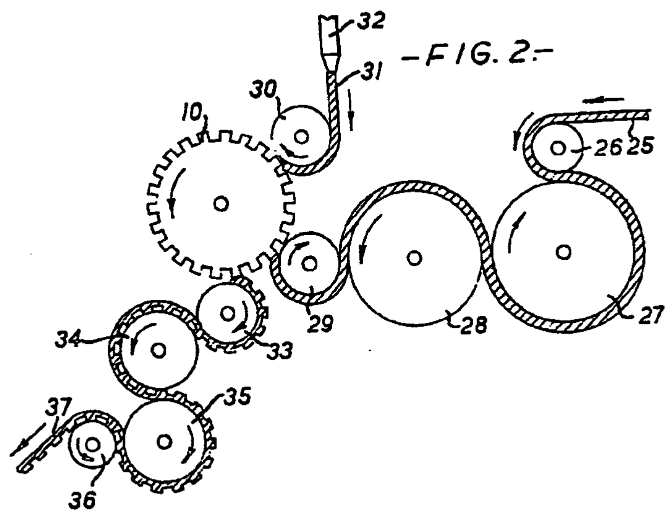
-FIG. 1-



-FIG. 2-



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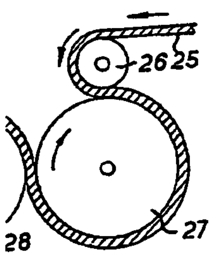
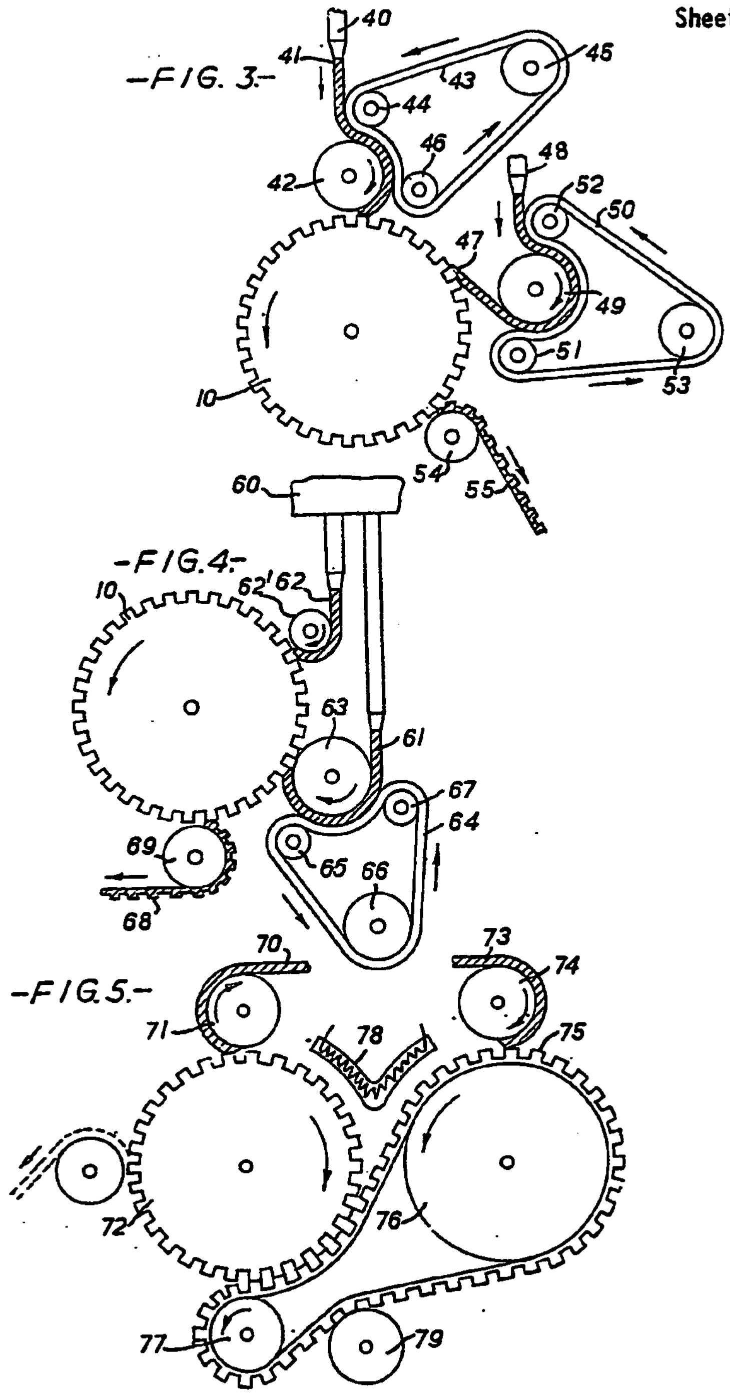


-FIG. 3.-

-FIG. 4.-

-FIG. 5.-



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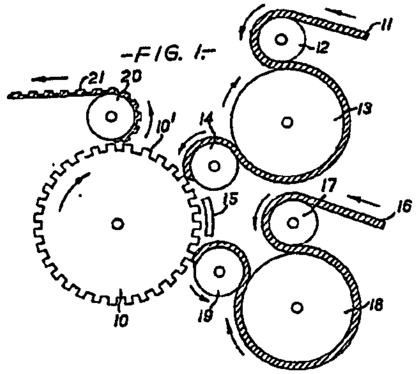

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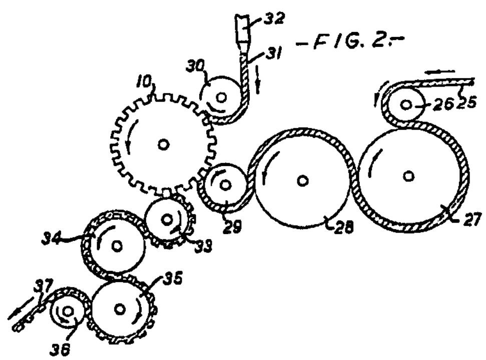

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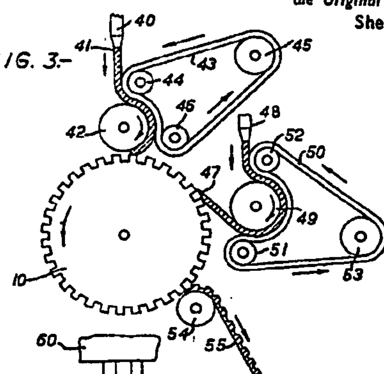

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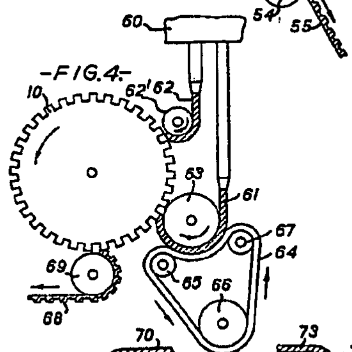
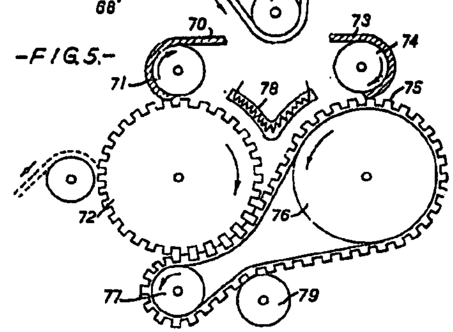


-FIG. 5.-



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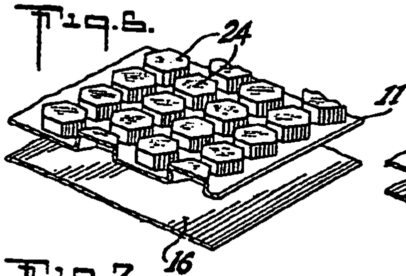
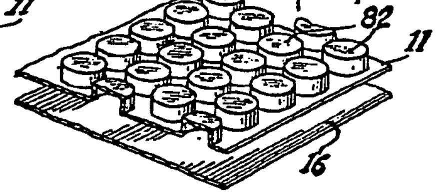


Fig. 11.



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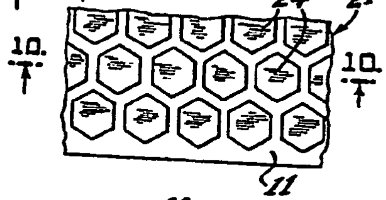


Fig. 12.

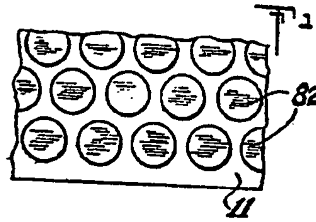


Fig. 8.

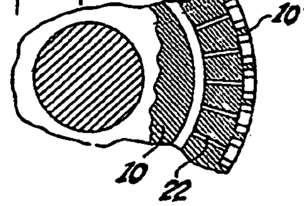


Fig. 9.

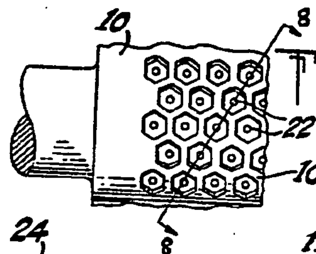


Fig. 10.

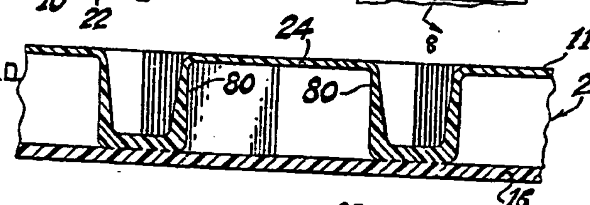


Fig. 13.

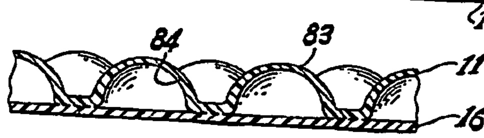
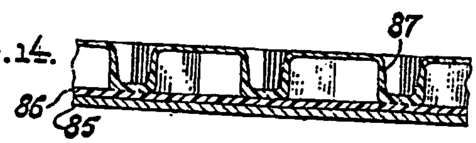


Fig. 14.



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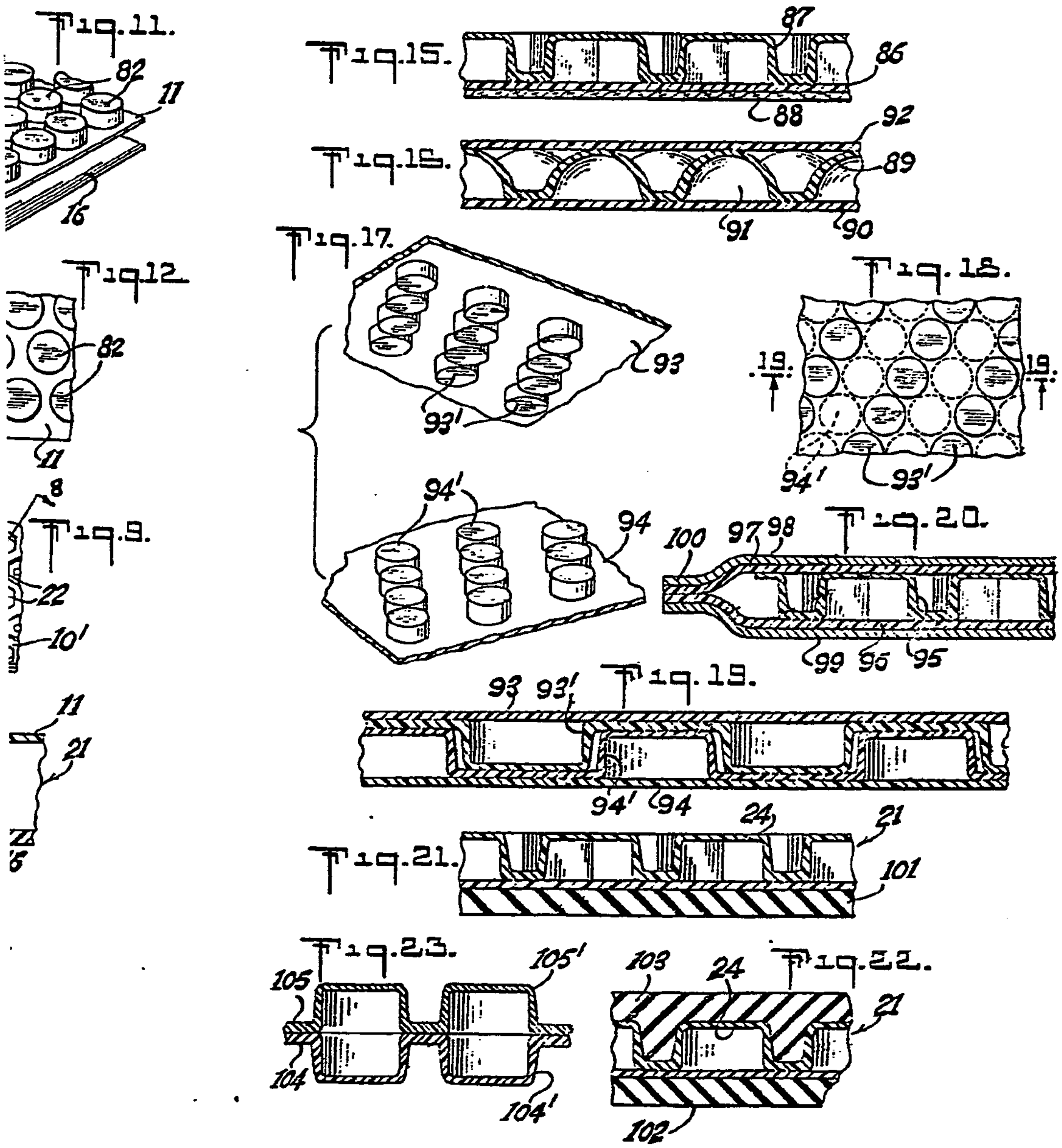

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